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Regional Difference in Specialization Coefficients of Physicians in Nagasaki, Japan

Susumu TANIMURA, Tsutomu MIZOTA

Department of Socio-environmental Medicine, Institute of Tropical Medicine, Nagasaki University, Nagasaki, Japan

In the comparison of municipalities with respect to the medical human resources, not only the number of physicians but also the distribution of their medical practice is important. The objective of the present study was to develop an index appropriate for comparing relatively small municipalities regarding the distribution of physician's medical practice and to apply it to Nagasaki Prefecture, Japan. We modified the specialization coefficient using Bayesian smoothing technique and used it as an index for comparing all municipalities except one in Nagasaki Prefecture. We computed the modified specialization coefficient using the number of physicians by medical practice and municipality as of the end of 2000. The modified specialization coefficient showed a considerable uniformity in the proportion of physicians among municipalities, while a relatively large variation among municipalities was observed in the proportion of pediatricians and psychiatrists.

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Keywords: Medical human resources; Bayesian estimate; Specialization coefficient

Introduction

The Constitution of Japan states that all Japanese shall equally receive health services irrespective of the place of residence (Articles 14 and 25). However, the recent policy of Japan to promote decentralization of authority has led to differences in health services among municipalities of Japan.[1]

As of the end of 2000, the physicians in Nagasaki Prefecture counted 3,637 or 239.8 per 100,000 population. This figure was much larger than that of the national level (201.5) and was the 9th largest among all of the 47 prefectures of Japan.[2] On the other hand, the age-adjusted mortality in Nagasaki Prefecture was rather high among all prefectures of Japan and was 6th and 23rd highest in males and females, respectively.[3] Such reverse observed in Nagasaki Prefecture between the rate of physicians and the mortality is probably caused by many factors, among which the difference in the distribution of physicians among municipalities may be important one. Indeed Nagasaki Prefecture government regards the distribution of physicians as one of the most important issues to resolve,[4] and has been making efforts to secure skilled physicians enough for all residents to receive sufficient health services everywhere in the prefecture. They have, however, paid attention mainly to the total number of physicians in respective areas and the possible regional variation in the proportion of physicians by medical practice has been ignored.

The objective of the present study was to evaluate the proportion of physicians by medical practice for municipalities of Nagasaki Prefecture using a regional economic study approach.

Materials and Methods

Study area

Nagasaki Prefecture is located at the northwest of Kyushu Island consisting of 8 cities, 70 towns and 1 village, among which 31 municipalities are in small islands (Figure 1). The population by municipality as of October 1, 2000 is depicted in Figure 2. Takashima town (No. 43), which consists of two small islands named Takashima and Hashima, was developed as a town of coalmine and the population was 23,000 in its golden age. However, since 1986 when the coalmine was closed, the population of the town has been decreasing to 900 as of October 1, 2000.

Address correspondence: Susumu Tanimura, Department of Socio-environmental Medicine, Institute of Tropical Medicine, Nagasaki University, 1-12-4 Sakamoto, Nagasaki 852-8523 JAPAN

TEL: +81-(0)95-849-7865, FAX: +81-(0)95-849-7867, E-mail: umusus@net.nagasaki-u.ac.jp

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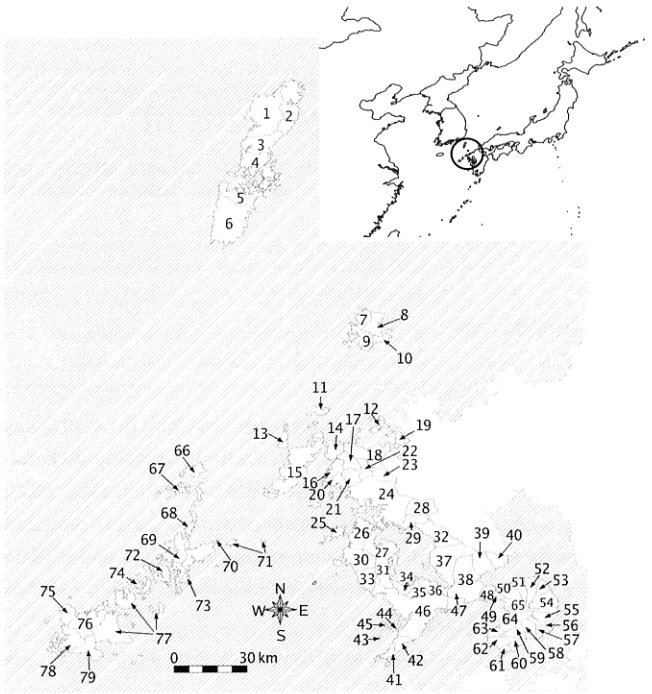

Figure 1. Two maps showing the location of Nagasaki Prefecture in Japan and that of respective municipalities of Nagasaki Prefecture. The circle in the upper right-hand map indicates the location of Nagasaki Prefectire in Japan. The name of the municipalities corresponding to the respective numerals is given in Table 2 at page 103.

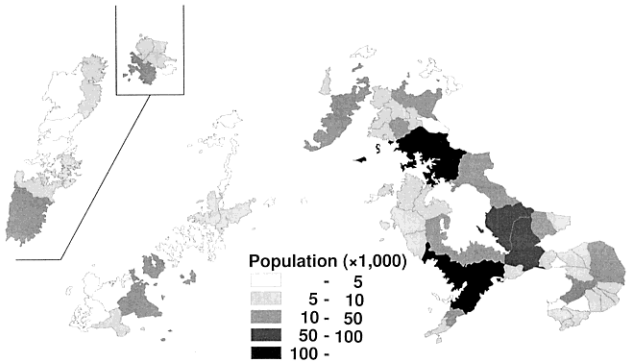

Figure 2. The distribution of the population by municipality in Nagasaki Prefecture. In the legend, the figures on the left side are included while those on the right side are excluded.

Data source

We used *Nagasaki Health Statistics 2000*[2] to obtain the number of physicians by medical practice as of the end of 2000 for each municipality of Nagasaki Prefecture. There were 3,637 medical doctors in total and the aggregated number of physicians classified according to the medical practice they reported was 6,278. The first 10 medical practices in descending order of the total number of respective physicians were: internal medicine (1,565 doctors or 24.9%), surgery (557 or 8.9%), gastroenterology (551 or 8.8%), pediatrics (399 or 6.4%), orthopedics (395 or 6.3%), cardiology (326 or 5.2%), rehabilitation (326 or 5.2%), pulmonology (247 or 3.9%), radiology (186 or 3.0%) and psychiatry (185 or 3.0%); the aggregated number of physicians who reported these medical practices was 4,737 (75.5%). We made a group consisting of the remaining medical practices and named it "others." Analysis of the uniformity in the proportion of medical practice among municipalities was conducted for the above-mentioned 10 categories of medical practice excluding "others."

Specialization coefficient

We first indroduce a simple index for evaluating the uniformity in the proportion of medical practice among municipalities. We denote the proportion of the medical practice j in the municipality i as θ_{ij}. Then $\Sigma_j \theta_{ij}=1$ by definition. The proportion of the medical practice j in the prefecture may be defined as the mean of θ_{ij}s for all municipalities, i.e. $\theta_{.j}=\Sigma_j \theta_{ij}/I$, where I denotes the number of municipalities. Then the following index will measure the discrepancy in the medical practice j between the municipality i and the prefecture:

$$\Psi_{ij}=\frac{\theta_{ij}}{\theta_{.j}}.$$

Note that if the proportion of the medical practice j is same in all municipalities, i.e. θ_{ij} is independent of i, then $\Psi_{ij}=1$. On the other hand, the index Ψ_{ij} exceeding 1 implies that the proportion of the medical practice j in the municipality i is larger than that in the prefecture.

Denoting by n_{ij} the number of physicians who reported the medical practice j in municipality i, we see that $n_{ij}/\Sigma_j n_{ij}$ and $\Sigma_i n_{ij}/\Sigma_i \Sigma_j n_{ij}$ estimate θ_{ij} and $\theta_{.j}$, respectively. Hence the index Ψ_{ij} is estimated by:

$$SC_{ij}=\frac{n_{ij}/\Sigma_j n_{ij}}{\Sigma_i n_{ij}/\Sigma_i \Sigma_j n_{ij}}.$$

This estimate is called the specialization coefficient and is frequently used in the field of regional economics.[5]

Modified specialization coefficient

Since the variance of ordinary estimate of the proportion θ_{ij} defined by $n_{ij}/\Sigma_j n_{ij}$ is $\theta_{ij}(1-\theta_{ij})/\Sigma_j n_{ij}$, the ordinary estimate is known to be unstable for small value of n_{ij}. The Bayesian approach is one way to overcome this difficulty. We assume that θ_{ij} is also distributed with mean γ_{ij} and variance ϕ_{ij}. Then the estimate of the following form is known to well behave.[6]

$$\hat{\theta}_{ij}=w_{ij}\left(\frac{n_{ij}}{\Sigma_j n_{ij}}\right)+(1-w_{ij})\gamma_{ij} \qquad (1)$$

where

$$w_{ij} = \frac{\phi_{ij}}{\phi_{ij} + \frac{\gamma_{ij}}{\Sigma_j n_{ij}}}. \quad (2)$$

The parameters γ_{ij} and ϕ_{ij} are estimated from the data and the above estimate is called empirical Bayes estimate. Note that the estimate coincides with the ordinary estimate of the proportion if the weight w_{ij} is 1, while it is equal to a prior estimate γ_{ij} if the weight w_{ij} is 0. We note furthermore that the weight approaches 1 or 0 according as $\Sigma_j n_{ij}$ increases to infinity or decreases to 0.

Estimating θ_{ij} by $\hat{\theta}_{ij}$ instead of $n_{ij}/\Sigma_j n_{ij}$, we obtain an empirical Bayes estimate of Ψ_{ij}:

$$SC_{ij}^{*} = \frac{\hat{\theta}_{ij}}{\Sigma_i n_{ij} / \Sigma_i \Sigma_j n_{ij}}. \quad (3)$$

We call SC_{ij}^{*} the modified specialization coeeficient. See Appendix for the explicit form of the modified specialization coefficient.

Results

Distribution of doctors

The distribution of the number of physicians by municipality is shown in Figure 3. The number of physicians was less than 10 in 48 (60.8%) municipalities; 10-49 in 25 (31.6%); 50-99 in 2 (2.5%); 100-499 in 2 (2.5%); and 500 or more in 2 (2.5%) municipalities, respectively. Figures 2 and 3 indicate a high correlation between the number of physicians and population in each municipality. Indeed, Spearman's rank correlation coefficiet was 0.85 ($p<0.0001$).

A closer observation of Figures 2 and 3, however, reveals , some municipalities with relatively smaller or larger number of physicians as compared to their population. Figure 4 depicts the distributions of the number of physicians per 100,000 population by municipality in Nagasaki Prefecture. The rate per 100,000 population was less than 50 in 13 (16.5%) municipalities; 50-100 (including 50 and excluding 100) in 27 (34.2%); 100-200 in 25 (31.6%); 200-300 in 9 (11.4%); and 300 or more in 5 (6.3%) municipalities, respectively. Among 13 municipalities with the rate per 100,000 equal to or more than 200 (cf. 201.5 of the national avearge), there were 6 small towns with population less than 10,000: Tabira (No. 14), Emukae (No. 17), Konagai (No. 40), Aino (No. 49), Kuchinotsu (No. 61) and Kamigoto (No. 69). On the other hand, among 23 municipalities with population equal to or larger than 10,000, the number of physicians per 100,000 population was less than 100 in 3 towns: Nagayo (No. 35), Kunimi (No. 52) and Ariake (No. 53).

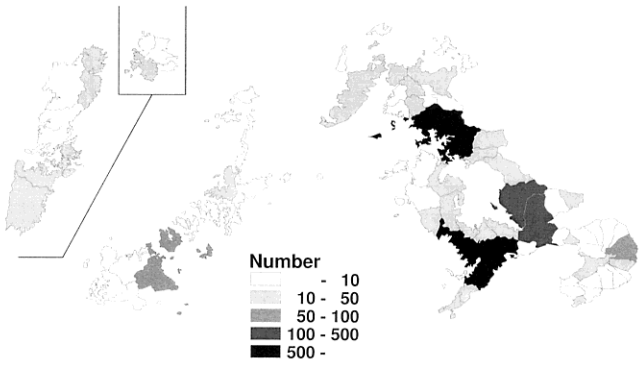

Figure 3. The distribution of the number of physicians by municipality in Nagasaki Prefecture. In the legend, the figures on the left side are included while those on the right side are excluded.

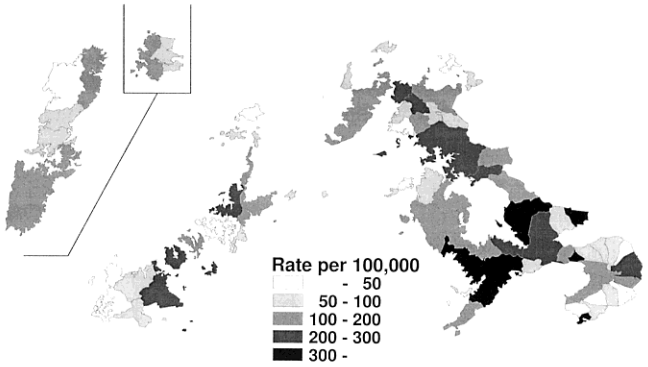

Figure 4. The distribution of the number of physicians per 100,000 population by municipality in Nagasaki Prefecture. In the legend, the figures on the left side are included while those on the right side are excluded.

Modified specialization coefficient

Excluding Takashima (No. 43) with no physicians, we estimated the mean γ_{ij} and variance ϕ_{ij} of the prior distribution for the proportion θ_{ij} of the medical practice j in the municipality i by assuming that they are independent of i, i.e. $\gamma_{ij} = \gamma_j$ and $\phi_{ij} = \phi_j$. These estimates and the minimum and maximum values of the weight w_{ij} are given in Table 1 for each medical practice. We note that the ag-

Table 1. Estimates of the mean and variance of the prior distribution, and the minimum and maximum of the weight for each medical practice

Medical practice	Mean (γ)	Variance (ϕ)	Weight[b]
Internal medicine	0.24928	0.000029	0.0001-0.2300[c]
Pulmonology	0.03934	0.000073	0.0019-0.8265
Gastroenterology	0.08777	0[a]	0
Cardiology	0.05193	0[a]	0
Pediatrics	0.06356	0.001403	0.0216-0.9827
Surgery	0.08872	0.000440	0.0049-0.5602
Orthopedics	0.06292	0[a]	0
Rehabilitation	0.05193	0.000082	0.0016-0.8022
Radiology	0.02963	0[a]	0
Psychiatry	0.02947	0.000285	0.0096-0.9613
Others	0.24546	0.001710	0.0069-0.9471

[a]The Equations (A7) and (A8) at page 105 resulted in negative values of ϕ for these medical practices and we set ϕ as 0.

[b]See Equation (2) for the definition.

[c]Minimum-Maximum.

gregated number of physicians varied from 1 to 2,586 among the municipalities.

Figure 5 compares the ordinary and modified specialization coefficients for the 10 medical practices. As was stated previously (page 100), the ordinary specialization coefficient varied largely among municipalities with relatively small number of physicians, e.g., up to 100 for each medical practice, while the modified specialization coefficient remained relatively stable irrespective of the number of physicians for each medical practice except for pulmonology, pediatrics, rehabilitation and psychiatry. We note that the ordinary and modified specialization coefficients were very close for large number of physicians irrespective of medical practice.

Table 2 compares the modified specialization coefficient among municipalities. The modified specialization coefficient for pulmonology was relatively large in Shimabara (No. 54). The municipalities with relatively small modified specialization coefficient for pediatrcis were Higashisonogi (No. 32), Togitsu (No. 34), Sanwa (No. 42), Aino (No. 49) and Shimabara (No. 54), and those with relatively large modified specialization coefficient for pediatrics were Mine (No. 3), Mitsushima (No. 5), Gonoura (No. 9), Ikitsuki (No. 13), Shikamachi (No. 16), Oshima (No. 25), Nagayo (No. 35), Konagai (No. 40), Nomozaki (No. 41), Kuchinotsu (No. 61), Ojika (No. 67), Shinuonome (No. 68), Kamigoto (No. 69), Arikawa (No. 70), Narao (No. 73), Naru (No. 74) and Fukue (No. 77). The modified specialization coefficient for surgery was relatively large in Matsuura (No. 18), and that for rehabilitation was relatively small in Sasebo (No. 24). The municipalities with relatively small modified specialization coefficient for psychiatry were Hirado (No. 15), Matsuura (No. 18), Kawatana (No. 29), Kinkai (No. 31), Togitsu (No. 34), Nagayo (No. 35) and Tarami (No. 36), and those with relatively large modified specialization coefficient for psychiatry were Izuhara (No. 6), Sechibaru (No. 23), Seihi (No. 27), Hasami (No. 28), Higashisonogi (No. 32), Omura (No. 37), Nomozaki (No. 41), Sanwa (No. 42) and Shimabara (No. 54).

Discussion

The present study indicated, from the viewpoint of the modified specialization coefficient for 10 medical practices, i.e. internal medicine, pulmonology, gastroenterology, cardiology, pediatrics, surgery, orthopedics, rehabilitation, radiology and psychiatry, that little difference was observed among municipalities except for pulmonology, pediatrics, rehabilitation and psychiatry. However, factors to influence the modified specialization coefficient should be scrutinized.

The data used in this study was based on the national survey of physicians, dentists and pharmacists, which is conducted biennially by the Ministry of Health, Labour and Welfare. All physicians must answer the questions irrespective of the status of their medical practice at the time of the survey. Physicians were counted at their main place of work at the time of the survey; not at their residence or the place of part-time work.[2] Although physicians were requested to report their main medical practice as well as all medical practices they are engaged in, some of them only reported medical practices they are engaged in without indicating their main medical practice. Furthermore, no information was available on the proportion of time

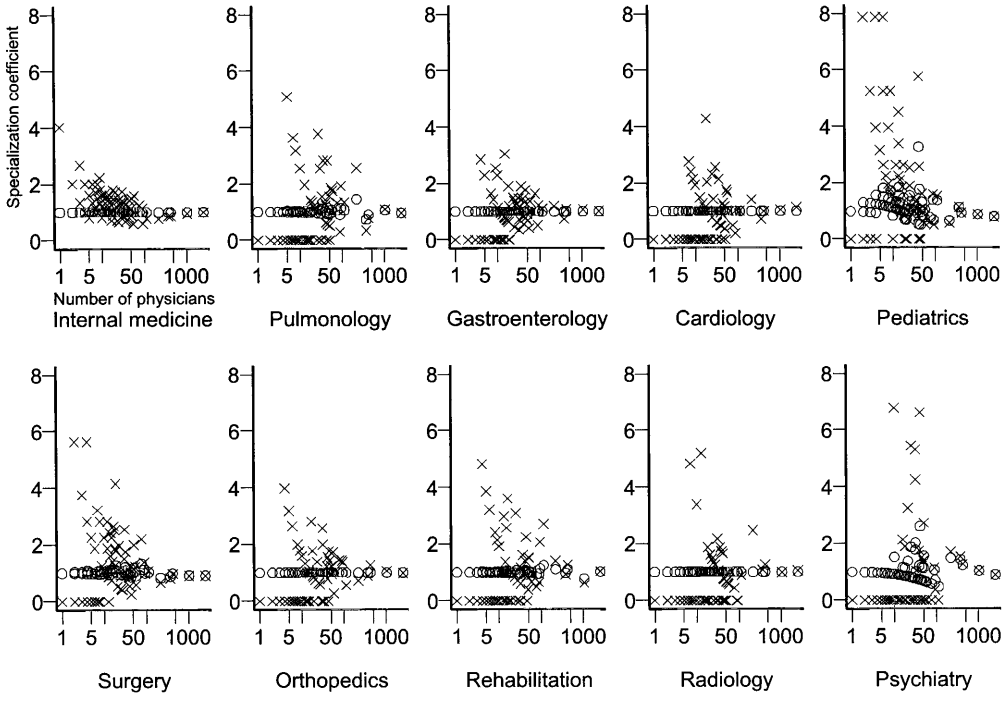

Figure 5. Scatter plots of the total number of doctors and specialization coefficients by municipality for each medical practice. The symbols × and ○ represent the ordinary and modified specialization coefficients, respectively.

Table 2. Modified specialization coefficients by municipality for 10 medical practices

No.[a]	Municipality	Medical practice									
		Internal medicine	Pulmonology	Gastroenterology	Cardiology	Pediatrics	Surgery	Orthopedics	Rehabilitation	Radiology	Psychiatry
1	Kamiagata	1.0006	0.9945	1	1	0.9379	0.9854	1	0.9953	1	0.9718
2	Kamitsushima	1.0005	0.9854	1	1	1.1451	1.0693	1	0.9875	1	0.9283
3	Mine	1.0002	0.9890	1	1	1.4966	1.0254	1	0.9906	1	0.9452
4	Toyotama	1.0006	0.9945	1	1	1.2637	0.9854	1	0.9953	1	0.9718
5	Mitsushima	1.0005	0.9782	1	1	1.3398	1.1020	1	0.9814	1	0.8961
6	Izuhara	0.9995	0.9440	1	1	1.1967	1.0078	1	0.9808	1	1.7656
7	Katsumoto	0.9994	0.9694	1	1	1.2323	1.1283	1	0.9739	1	0.8589
8	Ashibe	0.9986	1.1142	1	1	1.1378	0.9908	1	1.0325	1	0.7419
9	Gonoura	1.0008	1.0463	1	1	1.3147	1.0293	1	0.9564	1	1.1237
10	Ishida	1.0006	0.9872	1	1	1.1670	1.0744	1	0.9891	1	0.9367
11	Oshima	1.0002	0.9963	1	1	1.2904	0.9902	1	0.9969	1	0.9810
12	Takashima	1.0004	0.9981	1	1	0.9784	0.9951	1	0.9984	1	0.9904
13	Ikitsuki	1.0009	0.9854	1	1	1.4404	1.0693	1	0.9875	1	0.9283
14	Tabira	1.0013	1.0312	1	1	0.9804	1.0035	1	1.0083	1	1.0069
15	Hirado	1.0029	0.9136	1	1	0.9606	1.1995	1	1.0380	1	0.6699
16	Shikamachi	1.0009	0.9782	1	1	1.3398	0.9966	1	0.9814	1	0.8961
17	Emukae	1.0026	1.0813	1	1	1.0195	1.0651	1	0.9548	1	0.7753
18	Matsuura	1.0022	1.0400	1	1	0.7563	1.3302	1	0.9458	1	0.5734
19	Fukushima	1.0005	0.9926	1	1	1.2381	1.0353	1	0.9937	1	0.9628
20	Kosaza	1.0006	0.9945	1	1	1.2637	0.9854	1	0.9953	1	0.9718
21	Saza	0.9987	1.0205	1	1	0.9107	0.9785	1	0.9993	1	1.2026
22	Yoshii	1.0006	0.9729	1	1	1.2732	0.9828	1	1.0363	1	0.8734
23	Sechibaru	0.9998	0.9818	1	1	1.1037	1.0060	1	1.0144	1	1.5099
24	Sasebo	0.9944	1.0544	1	1	0.8690	0.9124	1	0.7734	1	1.0249
25	Oshima	1.0002	0.9890	1	1	1.4966	1.0254	1	0.9906	1	0.9452
25	Oshima	1.0002	0.9963	1	1	1.2904	0.9902	1	0.9969	1	0.9810
26	Saikai	0.9998	1.0133	1		0.9642	1.0207	1	0.9724	1	0.8519
27	Seihi	1.0014	0.9440	1	1	0.9931	1.1042	1	0.9808	1	2.0161
28	Hasami	0.9993	0.9583	1	1	0.8055	1.0252	1	1.0396	1	1.5586
29	Kawatana	0.9973	1.0786	1	1	0.7654	1.0492	1	1.0040	1	0.6530
30	Oseto	1.0016	0.9677	1	1	0.9642	1.1232	1	1.0019	1	0.8519
31	Kinkai	0.9990	0.9665	1	1	1.0244	1.0460	1	0.9904	1	0.6970
32	Higashisonogi	1.0018	1.0079	1	1	0.6832	0.9563	1	0.9973	1	1.3765
33	Sotome	1.0011	1.0115	1	1	0.7045	1.2712	1	0.9709	1	0.8449
34	Togitsu	0.9957	1.1344	1	1	0.6688	0.9904	1	1.1371	1	0.6994
35	Nagayo	0.9970	1.0590	1	1	1.3709	1.0316	1	1.2598	1	0.4759
36	Tarami	1.0040	1.0731	1	1	1.0478	0.9069	1	0.9718	1	0.6409
37	Omura	0.9935	0.7288	1	1	1.1186	0.8775	1	0.9719	1	1.4219
38	Isahaya	0.9932	0.9010	1	1	0.9307	0.9857	1	1.1069	1	1.2209
39	Takaki	1.0011	0.9729	1	1	1.0122	1.0868	1	0.9769	1	0.8734
40	Konagai	0.9999	1.0170	1	1	3.2600	0.9240	1	0.9963	1	0.7163
41	Nomozaki	1.0013	0.9557	1	1	1.5397	0.9395	1	0.9620	1	1.8618
42	Sanwa	0.9999	0.9731	1	1	0.5249	0.9704	1	1.0249	1	2.5950
44	Koyagi	1.0001	1.0337	1	1	1.1670	0.9665	1	0.9891	1	0.9367
45	Iojima	1.0002	0.9963	1	1	0.9577	1.0455	1	0.9969	1	0.9810
46	Nagasaki	0.9985	0.9588	1	1	0.7880	0.9071	1	1.0220	1	0.8898
47	Iimori	1.0004	0.9836	1	1	1.1240	1.0108	1	1.0160	1	0.9200
48	Moriyama	1.0008	1.0225	1	1	1.0469	0.9920	1	0.9799	1	0.8884
49	Aino	1.0022	1.1406	1	1	0.5016	0.8634	1	0.9337	1	1.1540
50	Azuma	1.0007	1.0281	1	1	0.8191	1.0592	1	0.9845	1	0.9119
51	Mizuho	1.0002	0.9818	1	1	1.1037	1.0060	1	1.0144	1	0.9119
52	Kunimi	0.9990	1.0007	1	1	1.3159	0.9892	1	1.0790	1	0.8054
53	Ariake	1.0008	1.0225	1	1	1.0469	0.9395	1	1.0395	1	0.8884
54	Shimabara	0.9942	1.4488	1	1	0.6476	0.8278	1	1.1046	1	1.4784
55	Fukae	1.0011	1.1319	1	1	1.0618	0.9313	1	0.9883	1	0.7931
56	Futsu	1.0000	0.9926	1	1	0.9188	0.9806	1	1.0239	1	0.9628
57	Arie	1.0000	1.0318	1	1	1.1451	0.9619	1	1.0176	1	0.9283
58	Nishiarie	1.0002	0.9747	1	1	1.2946	1.0396	1	1.0081	1	0.8809
59	Kitaarima	0.9999	0.9908	1	1	1.2134	0.9758	1	1.0223	1	0.9539
60	Minamiarima	1.0000	0.9712	1	1	0.9957	1.0300	1	1.0643	1	1.1501
61	Kuchinotsu	1.0011	0.9261	1	1	1.7604	1.0085	1	1.0788	1	0.7065
62	Kazusa	0.9992	1.0043	1	1	0.8936	1.0982	1	0.9943	1	0.8182
63	Minamikushiyama	1.0000	0.9782	1	1	1.0652	1.0493	1	0.9814	1	0.8961
64	Obama	1.0006	0.9456	1	1	1.0061	1.2057	1	0.9533	1	0.7695
65	Chijiwa	1.0001	1.0115	1	1	0.9492	1.0671	1	1.0004	1	0.8449
66	Uku	1.0005	0.9926	1	1	0.9188	1.0901	1	0.9937	1	0.9628
67	Ojika	1.0005	0.9926	1	1	1.5573	0.9806	1	0.9937	1	0.9628
68	Shinuonome	1.0002	0.9747	1	1	1.8254	1.0918	1	0.9784	1	0.8809
69	Kamigoto	1.0007	0.9677	1	1	1.4614	1.0719	1	0.9724	1	1.1312
70	Arikawa	1.0007	0.9747	1	1	1.5600	1.0396	1	1.0081	1	0.8809
71	Sakito	1.0005	0.9926	1	1	1.2381	0.9806	1	0.9937	1	0.9628
72	Wakamatsu	1.0001	0.9945	1	1	1.2637	1.0404	1	0.9953	1	0.9718
73	Narao	1.0007	0.9890	1	1	1.8033	0.9711	1	0.9906	1	0.9452
74	Naru	1.0008	0.9836	1	1	1.7037	1.0108	1	0.9860	1	0.9200
75	Miiraku	1.0002	0.9890	1	1	1.1898	1.0254	1	1.0207	1	0.9452
76	Kishiku	1.0004	1.0375	1	1	1.2134	1.0303	1	0.9922	1	0.9539
77	Fukue	1.0013	0.8988	1	1	1.3918	1.1203	1	0.9568	1	1.0665
78	Tamanoura	1.0001	0.9945	1	1	1.2637	1.0404	1	0.9953	1	0.9718
79	Tomie	1.0013	0.9836	1	1	1.1240	1.0108	1	1.0160	1	0.9200

[a]Same as that given in Figure 1. We excluded No.43 (Takashima) which had no physicians.

they were engaged in respective medical practices. We therefore treated a physician who reported two or more medical practices as independent physicians who reported respective medical practices.

In the calculation of the modified specializing coefficient, we made no assumptions about the form of the prior distribution and estimated its mean and variance by moment method assuming that mean and variance are constant throughout the municipalities. In the present study, this approach resulted in a negative estimate of variance for some medical practices and we set the estimate of variance at 0. An alternative approach to avoid such an estimate of the variance of the prior distribution is to assume the form of the prior distribution and estimate the parameters by the maximum likelihood method. One form of the prior distribution is the beta distribution, which is known as a conjugate prior distribution for the binomial distribution.

Since the original data were based on the voluntary reports from physicians, the variation in the quality of data may not be small among municipalities. Most of the physicians working at relatively large institutions probably reported only one among 10 medical practices shown in Table 2. On the other hand, most of the physicians working at small clinics or general practitioners probably reported two or more medical practices. For example, the medical practices reported by 24 physicians in Konagai (No. 40) were as follows: internal medicine-10; pulmonology-2; gastroenterology-2; cardiology-1; pediatrics-15; surgery-2; orthopedics-2; rehabilitation-2; radiology-2; psychiatry-0; and others-3. Obviously, there was duplication in doctors who reported internal medicine and pediatrics. In contrast to Konagai, none of 20 physicians in Sanwa (No. 42) reported pediatrics. The medical practices reported by them were as follows: internal medicine-10; pulmonology-1; gastroenterology-3; cardiology-2; pediatrics-0; surgery-3; orthopedics-4; rehabilitation-3; radiology-2; psychiatry-8; and others-7. Certainly, some physicians in Sanwa who reported internal medicine examine children and those who reported orthopedics read X-ray films. The medical practice other than main one reported by physicians was thus probably largely dependent on their individuality.

Oversimplification has been made in the present study regarding the comparison of the modified specialization coefficient for medical practice among municipalities. Firstly, we selected 10 medical practices simply becuase the number of physicians engaged in them were first 10 largest. Duplication of physicians would be probable among internal medicine, pulmonology, gastroenterology and cardiology, among surgery, pulmonology, gastroenterology and cardiology, and between orthopedics and rehabilitation. Some other medical practices classified as others in the present study may have shown differences in the proportion among municipalities. Secondly, we compared all municipalities ignoring their population and location. Physicians working at large institutions are mostly engaged in a specific medical practice, while those working at small clinics or general practitioners are usually engaged in two or more medical practices. Since large institutions are usually located in cities, it would be more informative to classify all municipalities into some groups on the basis of their location and population and compare the modified specialization coefficient among groups.

The present study is preliminary and not only the development of the present approach but also another study such as regional comparison of the size and function of medical institutions is necessary to elucidate the factors attributable to relatively high mortality as comapred to the number of physicians in Nagasaki Prefecture.

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References

1. Group for Developing Regional Indicator (Leader, Hashimoto S). *Development and Applications of Regional Indicators for Health and Welfare* (in Japanese). Report of Research on Applied Use of Statistics and Information, Health Sciences Research Grants 1997. Ministry of Health, Labour and Welfare, Tokyo, 1998
2. Nagasaki Prefecture. *Nagasaki Health Statistics 2000* (in Japanese). Nagasaki Prefecture, Nagasaki, 2002
3. Health and Welfare Statistics Association. Age-adjusted mortality by sex, year and prefecture (in Japaneses). *Journal of Health And Welfare Statistics* 50 (9 Suppl): 405, 2003
4. Nagasaki Prefecture. *Health Plan of Nagasaki Prefecture* (in Japanese). Nagasaki Prefecture, Nagasaki, 2001
5. Shaw G, Wheele D. *Statistical Techniques in Geographical Analysis*. John Wiley & Sons, Inc., Chichester, 1985
6. Langford IH. Using empirical Bayes estimates in the geographical analysis of disease risk. *Area* 26: 142-149, 1994

Appendix

Explicit form of the modified specialization coefficient

To avoid the unnecessary confusion, we denote the random variable corresponding to the observation n_{ij} by N_{ij}, the distribution of which is binomial with parameters $\Sigma_j n_{ij}$ and θ_{ij}. Hence,

$$E(N_{ij} \mid \theta_{ij}) = \Sigma_j n_{ij} \theta_{ij} \quad \text{(A1)}$$

$$V(N_{ij} \mid \theta_{ij}) = \Sigma_j n_{ij} \theta_{ij} (1 - \theta_{ij}) \quad \text{(A2)}$$

Bayesian estimation regards the parameter θ_{ij} itself as a random variable following some distribution (prior distribution to be exact) with mean γ_{ij} and variance ϕ_{ij}. If we estimate γ_{ij} and ϕ_{ij} from the data at hand, the resulting Bayes estimate is called the empirical Bayes estimate. Since only one observation is available for each set of i and j in the situation of the present study, we have to make some assumptions on γ_{ij} and ϕ_{ij}. The simplest approach is to assume

that the γ_{ij} and ϕ_{ij} are independent of i. That is $\gamma_{ij}=\gamma_j$ and $\phi_{ij}=\phi_j$ for all i.

To simplify the expression of the equations below, we introduce the following notations: $n_{..}$ denotes the total number of medical doctors, i.e. $n_{..}=\Sigma_i\Sigma_j n_{ij}$; $n_{.j}$ denotes the total number of doctors who reported medical practice j, i.e. $n_{.j}=\Sigma_i n_{ij}$; and $n_{i.}$ denotes the total number of doctors in municipality i, i.e. $n_{i.}=\Sigma_i n_{ij}$. Obviously, $n_{..}=\Sigma_i n_{i.}=\Sigma_j n_{.j}$.

Since

$$E(\theta_{ij})=\gamma_j$$

we see from (A1) that

$$E(N_{ij})=E_{\theta_{ij}}[E(N_{ij}\mid\theta_{ij})]=\Sigma_j n_{ij}E_{\theta_{ij}}(\theta_{ij})=\Sigma_j n_{ij}\gamma_j$$

or

$$E(\Sigma_i N_{ij})=n_{..}\gamma_j \tag{A3}$$

where $E(Y\mid X)$ denotes the conditional expectation of random variable Y given the random variable X and E_z denotes that expectation is taken with respect to the distribution of the random variable Z. Similarly, noting that

$$V(N_{ij})=E_{\theta_{ij}}[V(N_{ij}\mid\theta_{ij})]=V_{\theta_{ij}}[E(N_{ij}\mid\theta_{ij})]$$

and that

$$V(\theta_{ij})=\phi_j$$

we see that the following holds:

$$V(N_{ij})=\Sigma_j n_{ij}(n_{i.}-1)\phi_j+\Sigma_j n_{ij}\gamma_j(1-\gamma_j)$$

or

$$\Sigma_j n_{ij}V\left(\frac{N_{ij}}{n_{i.}}\right)=(n_{i.}-1)\phi_j+\gamma_j(1-\gamma_j)$$

Hence

$$\Sigma_i\Sigma_j n_{ij}V\left(\frac{N_{ij}}{n_{i.}}\right)=(n_{..}-I)\phi_j+I\gamma_j(1-\gamma_j)$$

or

$$\frac{\Sigma_i\Sigma_j n_{ij}V\left(\frac{N_{ij}}{n_{i.}}\right)}{n_{..}(1-I/n_{..})}=\phi_j+\frac{\gamma_j(1-\gamma_j)}{n_{..}/I-1}, \tag{A4}$$

where I denotes the total of the municipalities. Since $I/n_{..}$ is small as compare to 1 and since γ_j^2 is small as compared to γ_j, we may rewrite (A4) as

$$\frac{\Sigma_i\Sigma_j n_{ij}V\left(\frac{N_{ij}}{n_{i.}}\right)}{n_{..}}=\phi_j+\frac{\gamma_j}{n_{..}/I}. \tag{A5}$$

Since

$$V\left(\frac{N_{ij}}{n_{i.}}\right)=E\left[\frac{N_{ij}}{n_{i.}}-E\left(\frac{N_{ij}}{n_{i.}}\right)\right]^2=E\left(\frac{N_{ij}}{n_{i.}}-\gamma_j\right)^2,$$

Equation (A5) is rewritten as follows:

$$\frac{\Sigma_i\Sigma_j n_{ij}E\left(\frac{N_{ij}}{n_{i.}}-\gamma_j\right)^2}{n_{..}}=\phi_j+\frac{\gamma_j}{n_{..}/I} \tag{A6}$$

By equating the expectation of the random variable by the observed value, we can rewrite Equation (A3) and (A6) as follows:

$$n_{.j}=n_{..}\gamma_j \tag{A7}$$

$$\frac{\Sigma_i\Sigma_j n_{ij}\left(\frac{N_{ij}}{n_{i.}}-\gamma_j\right)^2}{n_{..}}=\phi_j+\frac{\gamma_j}{n_{..}/I} \tag{A8}$$

Substituting the solutions γ_j and ϕ_j of Equations (A7) and (A8) for γ_{ij} and ϕ_{ij} in Equation (2), respectively, we obtain the estimate of the weight w_{ij} and then the estimate θ_{ij} from Equation (1). Finally, we obtain the estimate of the modified specialization coefficient from Equation (3). We note that the denominator of the right-hand side of Equation (3) is equal to γ_j in the present estimation method. We also note that if Equations (A7) and (A8) resulted in a negative value of ϕ_j, we set ϕ_j at 0.